Effects of Convective Heating and Air-Sea Interaction on Tropical Cyclone Motion

P. I.: Bin Wang
Department of Meteorology, University of Hawaii,
2525 Correa Road, Honolulu, HI 96822
Phone: (808) 956-2563
Fax: (808) 956-2877
E-mail: bwang@soest.hawaii.edu

Co-P. I.: T. A. Schroeder
Department of Meteorology, University of Hawaii,
2525 Correa Road, Honolulu, HI 96822
Phone: (808) 956-7476
Fax: (808) 956-2877
E-mail: tas@soest.hawaii.edu

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http://www.soest.hawaii.edu/~bwang

LONG-TERM GOALS

Improve prediction of the tropical cyclone motion.

SCIENTIFIC OBJECTIVES

The specific scientific objectives of this study is to develop our physical understanding of the mechanisms by which convective heating and tropical cyclone-upper ocean interaction affect the baroclinic beta-drift of tropical cyclones.

APPROACH

Numerical experiments with a realistic hurricane model and a coupled hurricane-ocean model.
A new diagnositic approach for quantitative analysis of the effects of various processes governing tropical cyclone motion is developed to explain the numerical results.

WORK COMPLETED

1. We have developed and improved a coupled TC-ocean interaction model. The ocean model used is a modified version of the two and half layer tropical ocean model with intermediate level of complexity (Wang et al. 1995). The tropical cyclone model used is the hurricane model designed by Wang (1988) at the bureau of Meteorology Research Center. The model has 16 layer in the vertical and its physics (large-scale condensation, cumulus parameterization, precipitation

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evaporation, radiation cooling, and subgrid scale diffusion of momemtum, heat and moisture) is similar to the models that are currently used in operational forecast. Both models have a uniform grid spacing of 25 km and a domain of 201x 201 grids.

2. Developed a new diagnostic method based on potential vorticity (PV) tendency analysis. From the viewpoint of PV dynamics, a TC is characterized by a high value of positive PV anomaly concentrated within a radius of a few hundred kilometers from the center (Shapiro and Franklin 1995). Its movement can be viewed as due to propagation of PV anomalies in the absence of environmental flows. In this sense, the TC motion is affected by physical processes which determine total PV tendency. This method is particularly useful in quantitatively assessing the roles of various physical processes (horizontal and vertical advection of potential vorticity, diabatic heating, etc.) in TC propagation.

3. We revealed the factors that determine the propagation of a baroclinic tropical cyclone in the presence of convective heating and explained how the diabatic heating affects the beta drift.

4. We revealed the physical processes by which the TC-ocean interaction affects the propagation of the tropical cyclones.

RESULTS

1. Baroclinic tropical cyclone propagation in the presence of convective heating

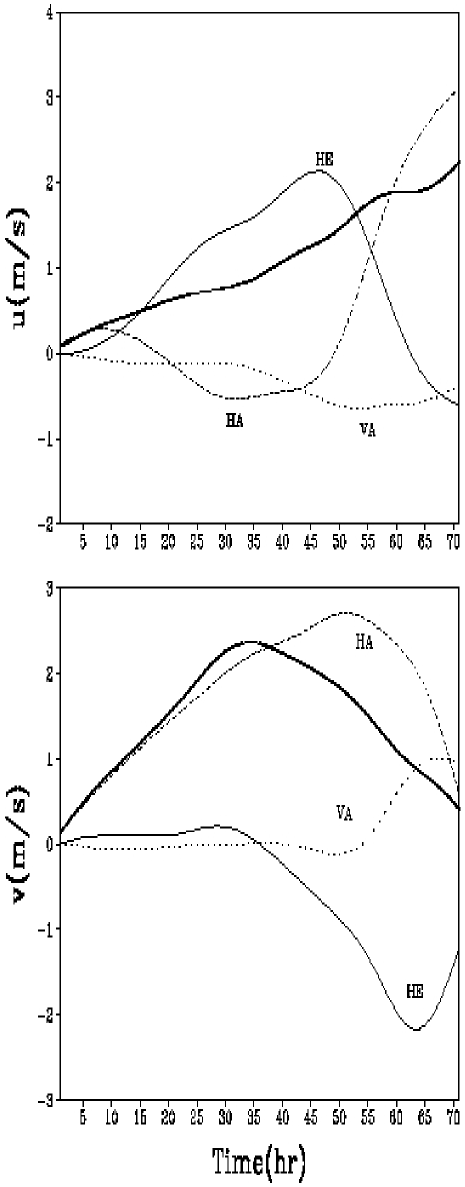
It is found that the diabatic vortex propagation is not necessarily due to horizontal PV advection by the asymmetric flows over the vortex core region. The contribution of various physical processes to TC propagation can vary with time (Fig.1), as well as with height (Fig.2). As shown in Figs. 2 and 3, the horizontal and diabatic heating are two dominant processes in TC propagation, while the vertical PV advection can play a significant role during the last 24 h. The influence of horizontal and vertical diffusion is negligible in this model.

The asymmetric diabatic heating can directly induce a positive PV tendency through the vertically differential heating. This positive PV tendency tends to induce a component of vortex propagation toward regions of maximum differential heating rate (Fig.3). On the other hand, the diabatic heating is azially asymmetric which induces a mesoscale asymmetric flow. The maximum differential diabatic heating tends to be located upstream of the asymmetric flows near the vortex center relative to the moving TC. Therefore, the influence of PV tendency caused by the asymmetric flows partly cancels the direct effect of the diabatic heating (Figs.1 and 3).

2. The influence of air-sea coupling on TC propagation

We compared the results of two numerical experiments in a resting environment on a beta-plane. The beta drift in the control run has fixed uniform SST of 28.5°C (CTL). The other run in the coupled model (CE) with the same initial SST as in the CTL. In agreement with Bender et al. (1993), the TC in CE moved more northward than the track in the CTL. The track difference is primarily caused by the difference of the asymmetric diabatic heating fields between the coupled

and uncoupled experiments. In the coupled experiment, the asymmetric diabatic heating is significantly reduced and its pattern shifts azimuthally. As a result, in the coupled experiment the diabatic heating contributes less to the equatorward propagation (Fig.4), thus the beta drift has a larger poleward component compared with that obtained in the CTL experiment (Fig.2).



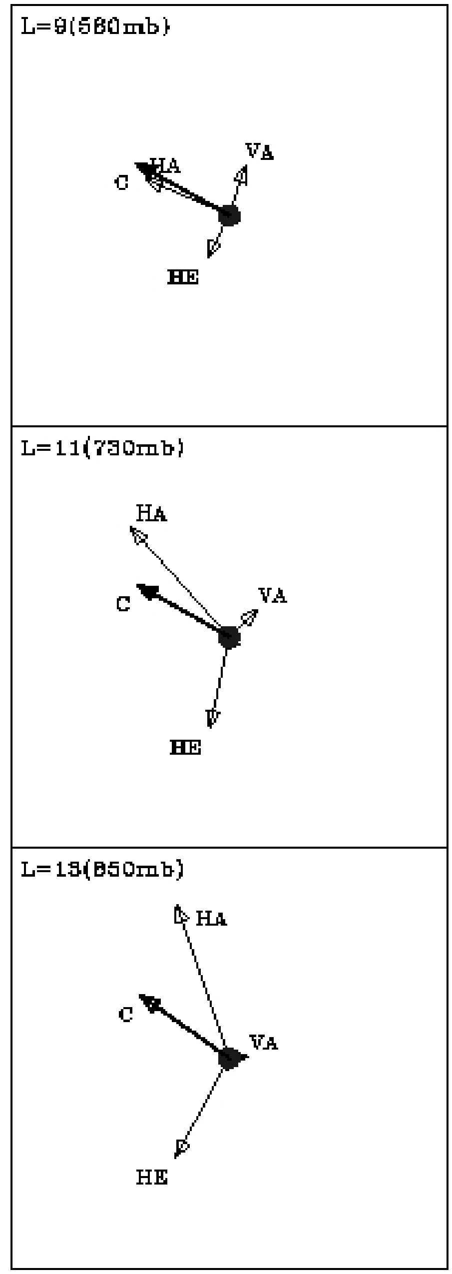


Fig.1 Time series of contributions of horizontal advection (dashed), diabatic heating (solid) and vertical advection (dotted) to zonal (upper panel) and meridional (lower panel) velocities at about 730 mb for CTL run. The thick solid line indicates the total contribution.

Fig. 2 Contributions of horizontal advection (HA), diabatic heating (HE) and vertical advection (VA) to the beta drift in

the indicated levels at 60h for CTL run. C indicates the vortex speed in the corresponding level.

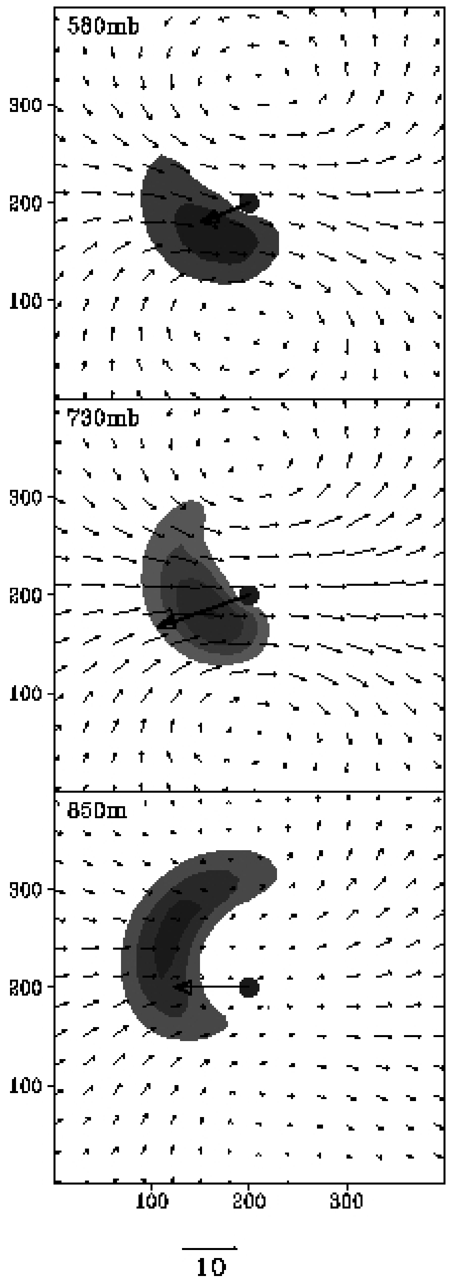


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Fig. 4 Same as in Fig. 2, but for the coupled experiment.

Fig. 3 Asymmetric wind fields relative to TC motion, differential diabatic heating (shaded) and the contribution of diabatic heating (thick arrows) to the beta drift at 48h for the control run.

RELATED PROJECT

A project entitled "Dynamics of Intertropical Convergence Zone and Tropical Cyclone Genesis" has been supported by Augmentation Awards for Science and Engineering Research Training (AASERT) (Award number N00014-95-1-1230, Mod No. A00003). Two graduate students have been supported by this grant. Mr. Patric Goda finished his Master Thesis, entitled "Four to six day oscillations in OLR and meridional wind in the eastern-central Pacific". Another graduate student, Kevin Mullen is currently working on this topic.

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PUBLICATIONS

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